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CORNING GLASS WORKS

ELECTRO-OPTICS LABORATORY

RALEIGH, NORTH CAROLINA

IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

Technical Report No. - 10a

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I. Materials Investigations

A program to obtain samples of a different class of materials, consisting of crystalline metallic oxides in a matrix of translucent Coram^R alumina, was initiated. In these materials the particle size, number density, and relative refractive index can be carefully controlled. Samples of Coram^R alumina, which contain magnesium oxide particles, have already been obtained.

Other samples, consisting of both glass-ceramics and Fotoform^R glasses, are due from our manufacturing facilities in Corning, New York. These will be evaluated as soon as possible and the results reported. From an analysis of these materials a new set of specifications will be formulated and forwarded for fabrication of improved samples.

Some time in the next period will be spent in evaluating competitive rear projection screen materials. It is important that we measure these other materials using our instrumentation as each different piece of equipment has different instrument factors which influence the data taken. This often makes a comparison of the data taken on two different instruments invalid; and, furthermore, it is sometimes difficult or impossible to correct the two sets of data for these instrument factors.

II. Theoretical Investigations

To make our theoretical work and subsequent experimental data as useful as possible, it is important that the angular scattering functions be normalized to yield the angular gain distribution function in its most meaningful form. There are two possible ways in which to normalize the angular scattering functions, and both use the same perfect isotropic scatterer as the reference to which they are normalized. This problem has been discussed in the open literature[1-8].

First, $Gain_1(\theta)$, can be defined as the ratio of power contained within a given solid angle, from an experimental screen to that from one composed of perfect isotropic scatterers, provided there is the same amount of power radiated into the forward hemisphere. Mathematically this can be stated as

$$Gain_1(\theta,\phi,\Delta\theta,\Delta\phi) = \frac{I(\theta,\phi)\Delta\theta,\Delta\phi/\iint_{\text{hemisphere}} I(\theta,\phi)d\theta,d\phi}{I_o(\theta,\phi)\Delta\theta,\Delta\phi/\iint_{\text{hemisphere}} I_o(\theta,\phi)d\theta,d\phi} \tag{1}$$

where $I(\theta,\phi)$ and $I_o(\theta,\phi)$ are the angular scattering function of the experimental screen and the isotropic screen respectively. The denominator of both the top and bottom of equation (1) represents the power scattered into the forward hemisphere.

The second, and more widely used approach, normalizes to the total incident power,

$$Gain_2(\theta,\phi\Delta\theta,\Delta\phi) = \frac{I(\theta,\phi)\Delta\theta,\Delta\phi/\iint_{\text{sphere}} I(\theta,\phi)d\theta,d\phi}{I_o(\theta,\phi)\Delta\theta,\Delta\phi/\iint_{\text{sphere}} I_o(\theta,\phi)d\theta,d\phi} . \tag{2}$$

Generally the scattering function is measured in the $\phi = o$ plane. For our application there is rotational symmetry, hence,

$$I(\theta,0) = I(0,\phi) . \tag{3}$$

Now let $\phi = o$, choose a value for $\Delta\phi$, and consider the gain function only dependent on θ. Clearly the integral in (2), over the sphere, is constant, and is independent of the scattering function, provided there is no absorption; thus,

$$\int \mathrm{Gain}_2(\theta)\,d\theta = K_2 . \tag{4}$$

If absorption exists; the effective transmittance is just

$$\mathrm{Transmittance} = \frac{\int \mathrm{Gain}_2(\theta)\,d\theta}{K_2} . \tag{5}$$

When comparing two different samples using $\mathrm{Gain}_2(\theta)$, not only can the relative shapes of the scattering functions be seen but there is also a direct indication of their relative efficiencies, Figure 1. The fraction of light scattered

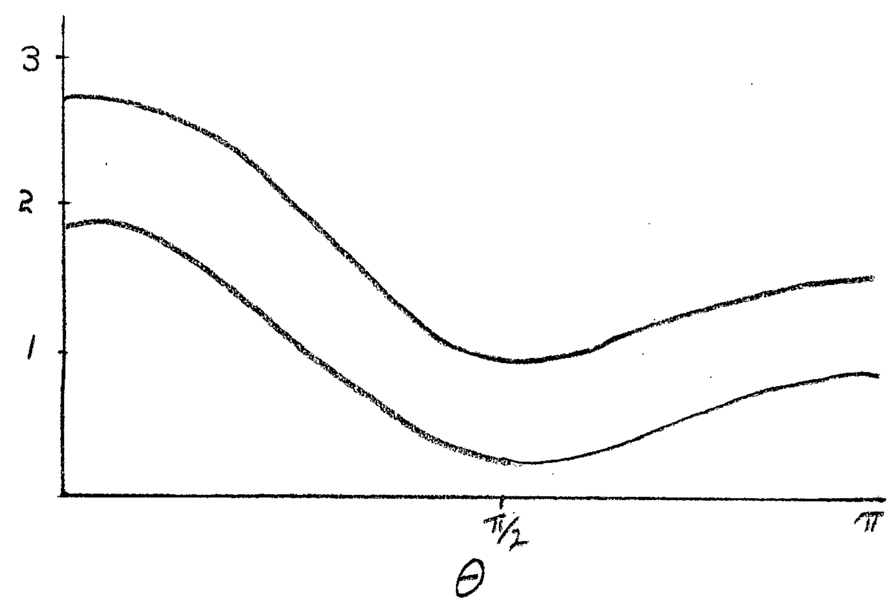

Figure 1. Comparison of two gain curves using $\mathrm{Gain}_2(\theta)$

into either hemisphere can be found by taking the ratios of the integral of $\mathrm{Gain}_2(\theta)$, over the proper hemisphere, to the integral over the full sphere.

If one chooses to use $\mathrm{Gain}_1(\theta,\phi)$ instead of $\mathrm{Gain}_2(\theta)$, only a comparison of the relative shape of the scattering function is possible. This can be seen by comparing two different rear projection screens. Let them both have scattering functions of the same shape in the forward hemisphere, and also let only screen #1 have some backscattering. The function $Gain_1(\theta)$ would show the two screens as having identical scattering properties, as it only has meaning to $\theta = \pi/2$. $Gain_2(\theta)$ would show the shape in the forward hemisphere to be identical; in addition, it would show that more incident power was required to get the same amount of power into the forward hemisphere of each screen. The ratio of the amount of input power, needed to scatter the same amount of power into the forward hemisphere, could also be computed from $Gain_2(\theta)$.

Assume now, the shapes of both scattering functions are identical over all angles, and let screen #1 have some neutral density. Again, the $Gain_1(\theta)$ curve would show both screens as being identical, while $Gain_2(\theta)$, besides showing the shapes to be identical, would also indicate that screen #1 is less efficient than the other; and an analysis of the function $Gain_2(\theta)$ would indicate by how much.

By now it should be clear that $Gain_2(\theta)$ is by far a more complete measure of the operational performance of a rear projection screen than is $Gain_1(\theta)$. $Gain_2(\theta)$ was used in computing the various data given in the Phase II Summary Report.

One additional word should be said about the isotropic, or as it is sometimes referred to, the Lambertian scatterer. By definition,it radiates uniformly in all directions. If we limit the size of a Lambertian screen, composed of Lambertian scatterers, by means of an opaque plate with a hole in it; we find the subtended area changes as cosine Ψ, Figure 2. This is equivalent to illuminating an area on a rear projection screen which is small compared to the angular field of view of the detector. The cosine Ψ term must be used to correct for the obliquity of the detector. On the other hand, if the field of view is held constant and is always filled by the screen, no angular correction is necessary.

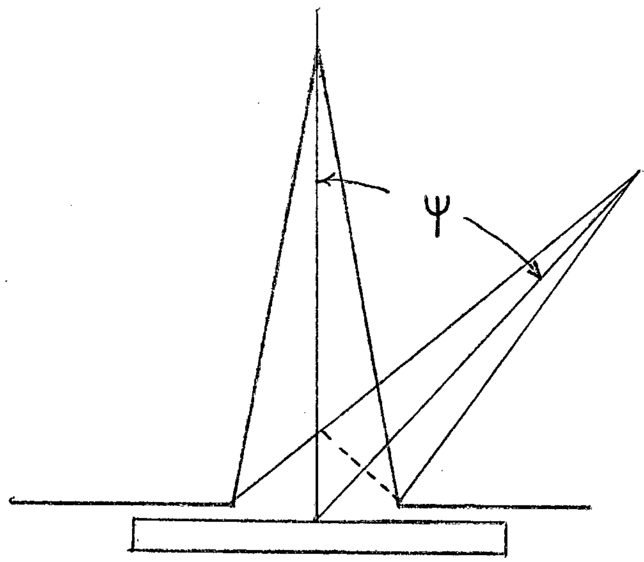

Figure 2. Geometry of the cosine correction for oblique viewing

III. Instrumentation

A. Goniophotometer

All mechanical and electrical work, including minor modifications, is complete. All of the optics in the collimator, and the detector have been aligned and the two sample holders have been adjusted to hold the samples normal to the incident beam. The angular resolution is better than $\pm 1^{\circ}$, which is set by play in the various gear trains, by the electronics of the servo system, by the collimation of the incident beam and by the size of the apertures in the detector unit.

To ensure as much signal as possible, the apertures in both the collimator and detector should be as large as can be tolerated. This is determined by measuring the scattering function of a typical screen using larger and larger apertures in the detector unit. At first no observable difference of the scattering functions will be seen. Finally an aperture size will be reached where the measured scattering function is significantly different from the others previously measured. This then is the first aperture which is too large; hence, the next smaller aperture is optimum in that it gives the best angular resolution and at the same time the most signal power. This aperture now sets the angular resolution of the instrument, and all other apertures should be optimized to give the same resolution.

This optimization of the goniophotometer is being concluded. Calibration and alignment procedures are being established. This is to ensure all of the data taken with it will have some common scale factor, thus permitting data, taken weeks apart, to be validly compared.

B. Modulation Transfer Function Analyzer

Construction of the MTF control console, including the control electronics, is finished; all that remains is the final adjusting of the motor speed controls. The rotating polarizer mount and film transport have also been completed and checked out.

Some preliminary MTF data on a rear projection screen have already been taken. A Fresnel zone plate made by interferometric techniques was used as the variable sine-wave pattern, Figure 3, and used in the optical system shown in Figure 4. Information on contrasts in the image with and without the screen were displayed on an oscilloscope and photographed. These data were then reduced to contrasts as a function of spatial frequency and subsequently to values for the MTF of the screen, Figure 5. This work was done primarily to check again our concept of the MTF analyzer. We found an oscilloscope to be quite useful for preliminary alignment, as only a few seconds are required for each data scan. However, because of the reduction in size of the display, con-

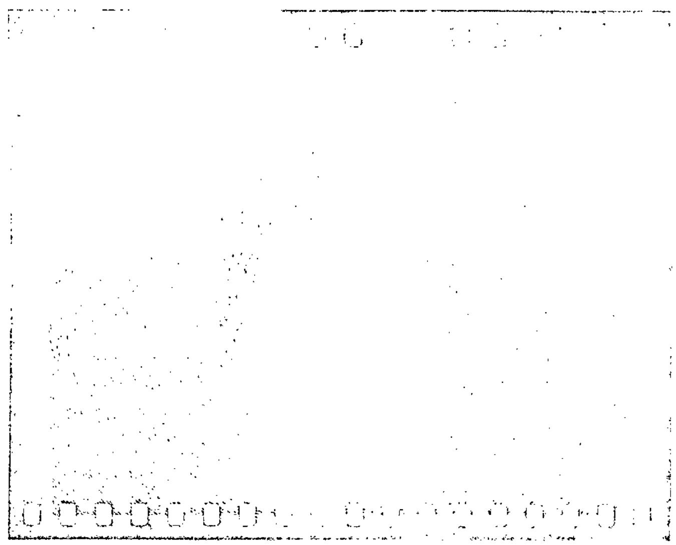

Figure 3. Fresnel zone plate type of sine-wave resolution target

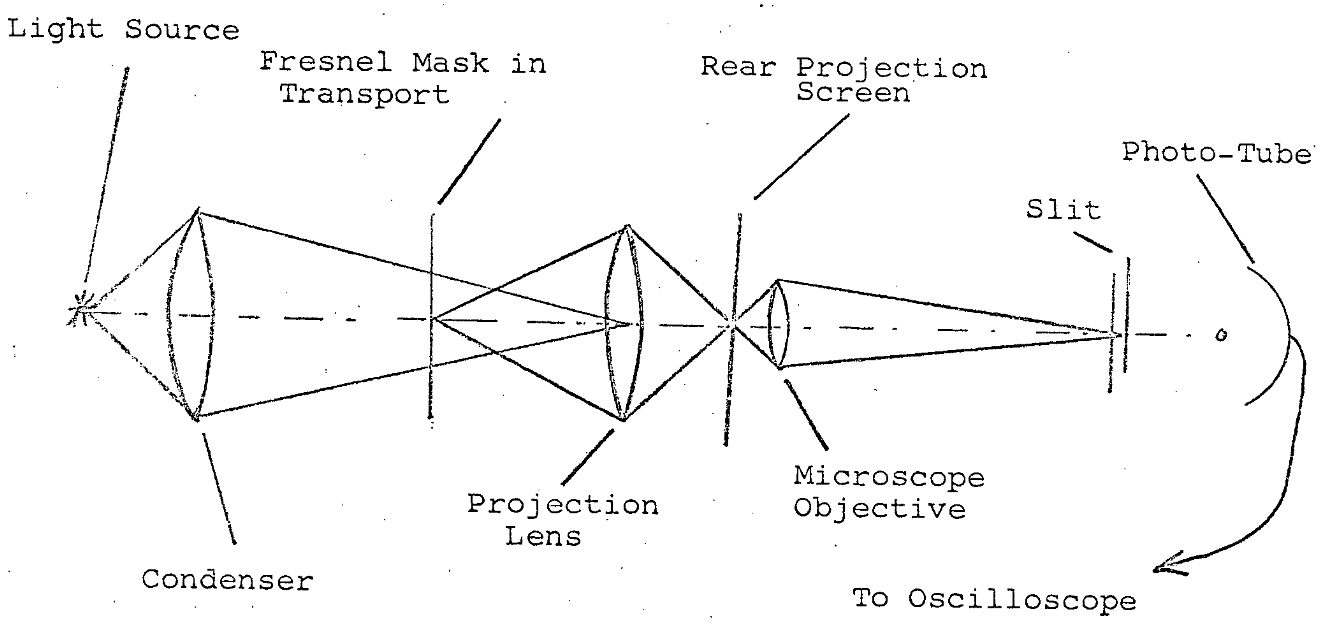

Figure 4. Optical system used to measure the MTF of a rear projection screen

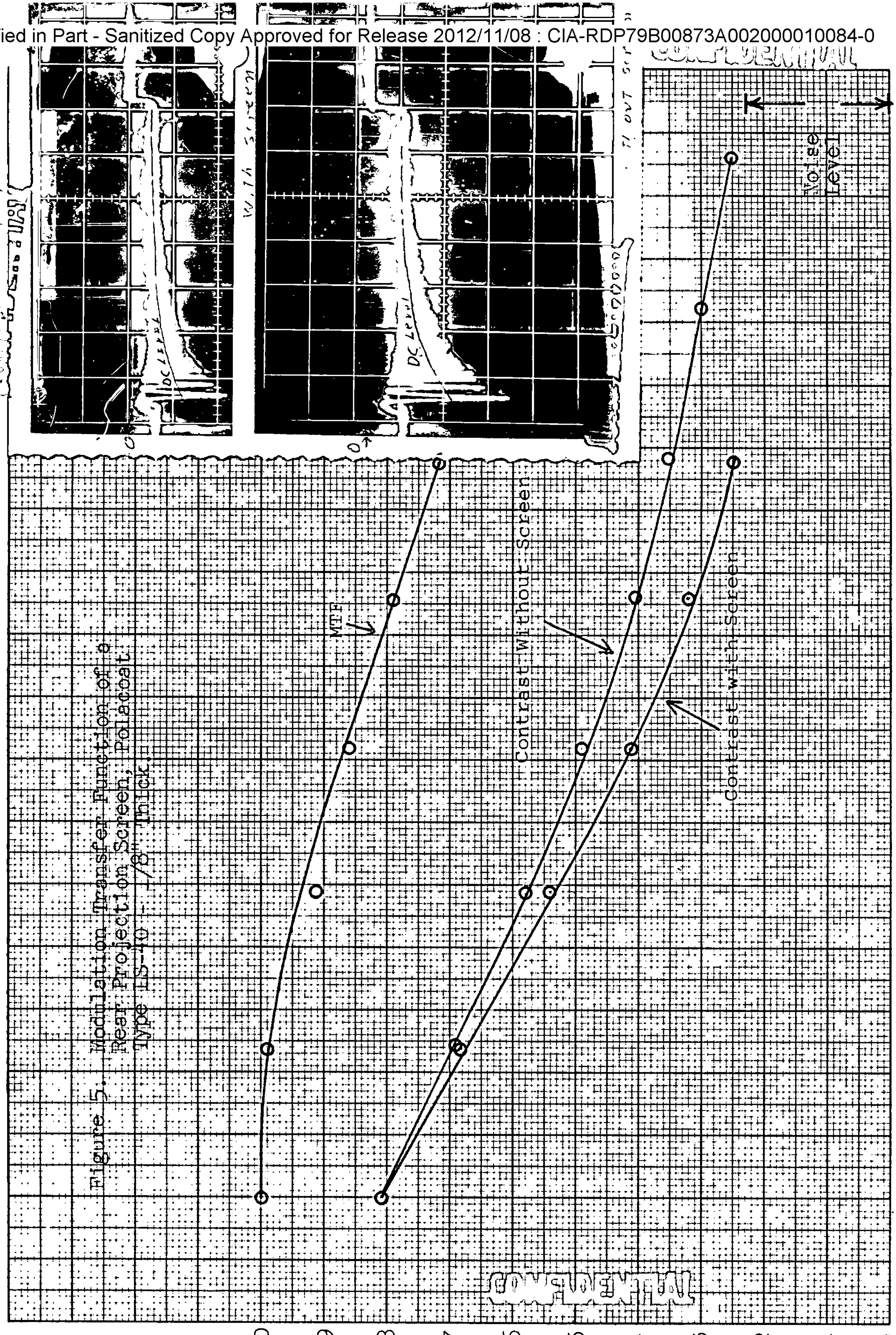

Figure 5. Modulation Transfer Function of a Rear Projection Screen, Polacoat Type LS-40 – 1/8" Thick

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siderable information is lost through uncertainties in measuring the photograph. Therefore, the x-y plotter in the main console is definitely required for the final recording of MTF data. An oscilloscope display should be considered for initial alignment.

The feasibility of using an interferometer to make sine-wave masks has been established. This approach is possible if some curvature of the fringes can be tolerated. Straight fringes can be obtained; however, the change of space frequency with position is too small to make these patterns of any value for the MTF analyzer. They are very good as constant spatial frequency patterns. Thus, the sine-wave masks must be formed in an unequal arm interferometer using a non-parallel beam of light which produces the conventional Fresnel zone plate type of mask, already shown.

Two different approaches will be followed in attempting to make the special sine-wave mask. In the first, a slit almost in contact with the film, will be illuminated by a cylinderical lens, Figure 6.

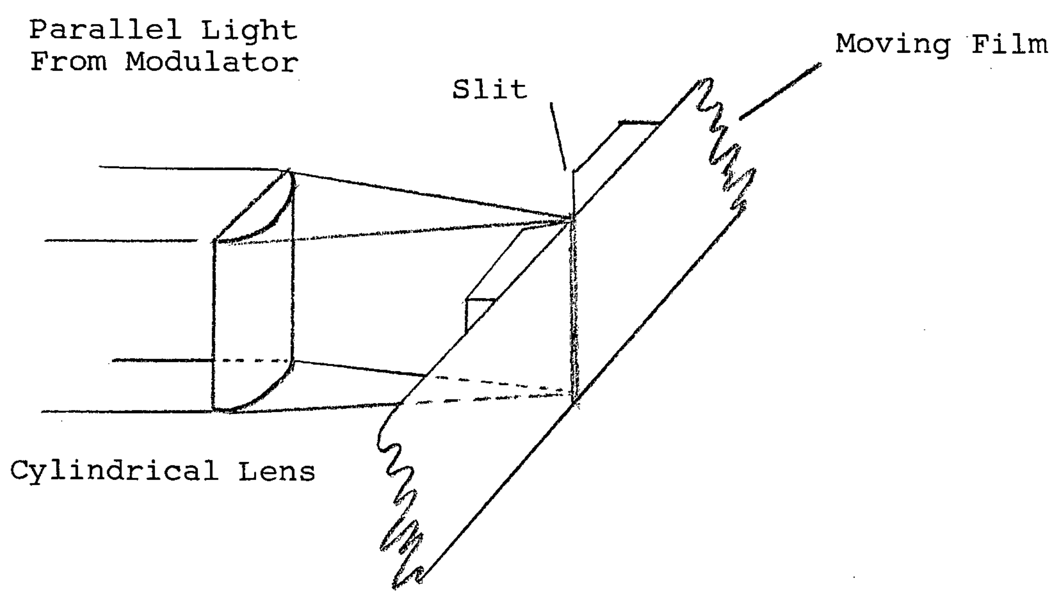

Figure 6. Making the sine-wave by placing a mechanical slit in contact with a moving emulsion

This slit is semi-adjustable down to 10 microns in diameter. In the second approach, a slit image will be directly projected onto the film by a high quality lens, Figure 7.

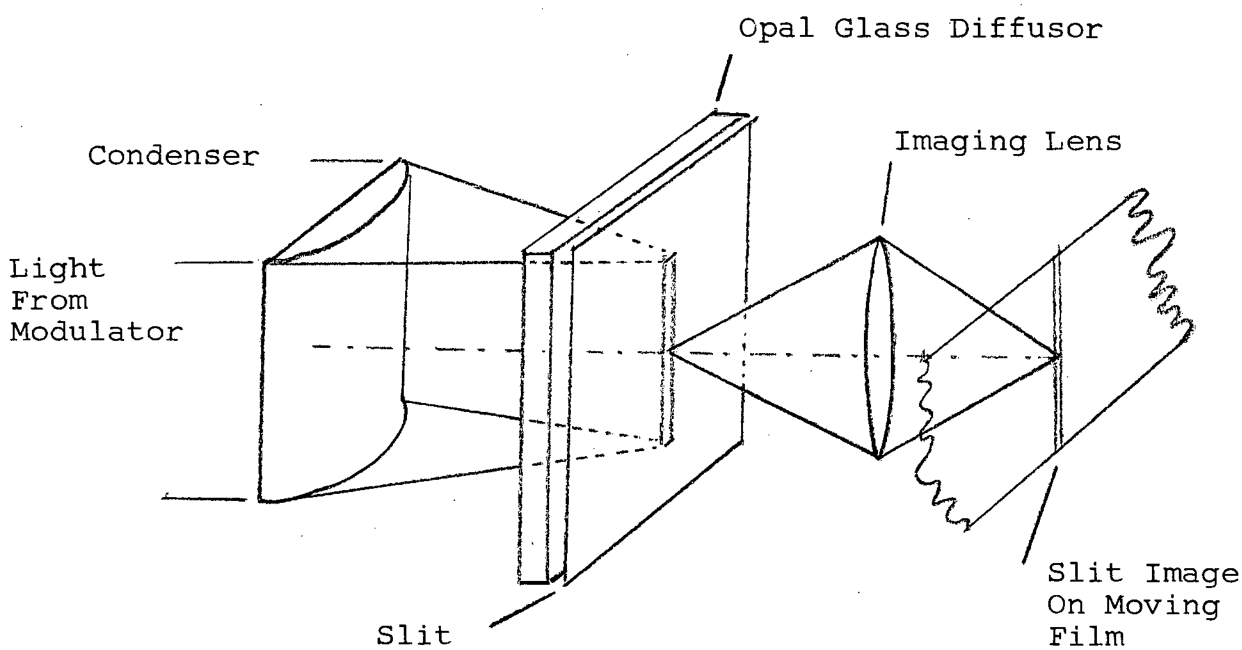

Figure 7. Making the sine-wave mask by projecting a slit image onto a moving emulsion

The slits for this approach are being made by shadowing very fine threads of wire on glass, with aluminum, and also by photographic reduction techniques. These slits will be projected onto the film at a reduction of about 3:1.

The first part of our effort to make the sine-wave masks will be concerned with determining the film characteristics and getting the individual components together and working as a system. The time requirement to complete this first phase is expected to be 1.5 weeks. A total of 4 weeks is scheduled in which to get the system working and the mask made. This effort begins the first of next period.

When the unit is to be used as a MTF analyzer, a photo-detector unit will be required. The basic detector design is complete, and the final design is scheduled to be completed before it is needed. The remaining electronics constituting the "contrast computer", which gives the MTF data, is being designed.

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